THE ANNIVERSARY ADDRESS OF THE PRESIDENT,

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[Read May 24, 1876.]

Recent Researches among some of the more simple Sarcode Organisms.

WHEN addressing you last year in fulfilment of the duty which annually devolves on your President, I believed that the object intended to be gained by this custom would be best carried out by making the Address as nearly as possible an exponent of recent progress in some special field of biological research.

I then selected for our subject the group of the true or ciliate Infusoria, and endeavoured to lay before you the principal steps by which our knowledge of these minute organisms had been recently advanced.

Guided on the present occasion by the same principle, I shall endeavour to treat in a similar way certain other groups in whose investigation much activity has shown itself within the last few years—simple sarcodic organisms, among which are, indeed, the simplest which it is possible to conceive—beings whose very simplicity give them a significance which can scarcely be overestimated in our investigations of the phenomena of life.

The limits, however, which must of necessity be imposed on the length of such an address render it impossible to treat the subject in all the details which an exhaustive exposition would involve. Much therefore, especially such as belongs to the description of special forms, must be omitted from our review; and I shall confine myself mainly to the results of observations which have made us acquainted with such forms and phenomena as have a more or less direct significance in their relation to morphological types and their bearing on physiological laws.

Most of the organisms which I propose to bring under review have probably their nearest relations with the animal rather than with the plant; but it must not be forgotten that the distinction is in many cases arbitrary, and that we have often no reliable character which will enable us to assert that the scarcely differentiated particle of protoplasm before us belongs to the animal kingdom rather than to the vegetable, or to the vegetable rather than to the animal.

This difficulty has been fully recognized by Haeckel, who has

included the whole of the organisms we are here about to consider in his group of PROTISTA, which he regards as composed of beings which are neither animals nor plants, and which thus form a third organic kingdom equivalent to the animal kingdom on one side, and to the vegetable on the other.

The advances which have of late years been made in our knowledge of the lowest forms of living beings are largely due to the important reform introduced by Max Schultze into the theory of the cell, when, by his researches on the Monothalamian Rhizopod *Cornuspira* *, the old conception of the cell as a membranous sac with contents gave place to the doctrine that in its original condition the cell represents only a naked lump of protoplasm with an imbedded nucleus ; and this doctrine gained further significance when he insisted on the fact, of fundamental importance in Biology, that the soft substance of the Rhizopoda, to which Dujardin had given the name of sarcode, was identical with the cell protoplasm of all higher animals and plants.

It was further shown by Haeckel † that there exists a great number of the lowest organisms whose structure is even simpler than had been imagined by Max Schultze; for in their naked protoplasmic bodies there is never to be found at any period of their lives a trace of a nucleus. He regards the nucleus as an essential constituent of the genuine "cell," which he views as the more highly developed elementary organism, and which ought to be carefully distinguished from the lower homogeneous, non-nucleated protoplasm mass, for which he proposes the name of "Cytode."

Both these forms of elementary organisms (the cell and the cytode) he embraces under the name of "Plastid," as being the builders-up of all complex organisms.

He regards this distinction of the two kinds of plastids as of the greatest importance in its bearing on the phylogenetic or genealogical history of organisms, since it is only such absolutely simple organisms as cytodes that can originate by spontaneous generation (*Urzeugung*), while it is only later on in the course of the development that cells become evolved from the cytodes by differentiation of an inner nucleus and an outer protoplasm.

In the greatest number of organisms the individuals take their

* "Ueber *Cornuspira*," Archiv für Naturg. 1860.

† 'Generelle Morphologie;' and "Beiträge zur Plastidentheorie," Jenaische Zeitschr. vol. v.

origin from nucleated cells, whether eggs or spores; and in these, as insisted on by Haeckel, genuine cytodes cannot occur. Here all the later plastids which compose them must have arisen from the genuine cell and, like this, must have been originally nucleated. If non-nucleated plastids, such as the red blood-corpuscles of Mammalia, should show themselves, these must have been produced by retrogradation—a loss of the nucleus in what was originally a genuine nucleated cell. In order to distinguish them from the true non-nucleated cytode, he gives them the designation of "Dyscytodes."

Among the forms which I am now about to bring before you, many examples of both true cells and cytodes will have to be adduced.

Hertwig and Lesser* have described a number of low *Amœba*-like organisms and of other rhizopodous forms of fresh water. They have worked out with much care their structure and affinities, and have attempted a general exposition of their organization and systematic position.

They all consist of masses of protoplasm in which a nucleus with nucleolus are almost always developed, and which, besides these, include a greater or smaller number of vacuoles, which may be either contractile or non-contractile. In the more purely amœboid forms their bodies have no definite shape, and are, for the most part, absolutely naked; but they are occasionally enveloped for a greater or less extent in a thin pellicle, which is excreted from the surface of the protoplasm, and follows all its changes of form, while, in rare cases, they are covered by foreign particles agglutinated together. In others, however (*Monothalamia*, Hert. & Less., and *Heliozoa*), there exist more definite protective structures either in the form of external hard shells or of firm membranous cases, or of variously arranged spines and spicules.

In morphological value none of them pass beyond the stage of a simple cell, or, at most, of two or more cells fused together into a single protoplasm-mass without any tendency to the formation of tissues or the differentiation of organs. In the protoplasm, however, may frequently be distinguished two layers or zones—an external layer (ectosarc), clearer and more homogeneous, and an internal layer (endosarc), less transparent and more loaded with granules. These two layers, for the most part, pass gradually into one another.

* "Ueber Rhizopoden und denselben nahestehende Organismen," Arch. f. mikr. Anat. vol. x. Suppl. 1874.

Hertwig and Lesser have paid especial attention to the structure of the nucleus, and have shown that in it and its contained nucleolus there is a remarkable constancy of character. The nucleus presents the appearance of a clear vesicle whose contents are either sparingly or not at all coagulable by acetic acid; while the nucleolus which it encloses is either a simple oval pale bluish body, or appears to have been broken up into several such bodies; it becomes granular in weak acetic acid, and in stronger acid swells up without becoming dissolved. In some cases the nucleus is seen to be bounded by a delicate structureless membrane-like layer (nucleus membrane), though in others no definite boundary layer can be demonstrated.

The same authors have distinguished in these organisms two kinds of locomotion. In one the contractility of the protoplasm affects equally the whole mass; the body changes but slightly its contour, and glides over the supporting object by a constant rotation of its whole surface, as is seen in *Hyalodiscus*, Hert. & Les. In the other, which is by far the more frequent condition, locomotion is effected by the contractility of limited portions of the surface, either causing the protrusion and retraction of blunt or pointed pseudopodia by means of which the organism is pushed or drawn forwards, or giving rise to a streaming forth of the protoplasm by which the whole body seems, as it were, to flow forward in a definite direction.

There is no definite orifice for the ingestion of nutriment, which gains access to the interior of the body solely by transmission through the surface of any part of the protoplasm which may be exposed to the surrounding medium. Solid nutritious matter thus becomes pressed into the deeper parts of the body, where during assimilation it may generally be seen accumulated in pellets surrounded by a clear liquid and included in a simple vacuole, from which the effete residue becomes afterwards expelled, and is finally ejected through any part of the exposed surface of the protoplasm. The attempt to confine the process of assimilation to the endosarc and of contractility to the ectosarc is not supported by careful observation. Indeed the absence of specialization in this most generalized phase of nutrition is further apparent from the fact that the whole process may take place even in a pseudopodium.

In almost every case, as already said, vacuoles occur distributed through the protoplasm. These are filled with a clear liquid, and are either variable in number and indefinite in position, or they

occupy a definite position and are then also definite in number. They mostly appear and disappear at intervals; and in those vacuoles which have a definite number and fixed position the appearance and disappearance follow one another at equal intervals, having thus a regularly rhythmical sequence. It is not easy, however, by any hard and fast line to separate these two classes of vacuoles from one another; even those with indefinite position and number sometimes show a rhythmical contraction, while they all pass by intermediate conditions into those irregular liquid-holding spaces so obvious in the protoplasm of plant-cells. It is these conditions which have induced Hertwig and Lesser, in opposition to the views of other zoologists, to assign little or no systematic value to the contractility of the vacuoles.

As may be expected in organisms of such extremely simple structure and with the functions of nutrition and irritability showing such little tendency to specialization, there is a corresponding simplicity in the function of reproduction. This, indeed, is probably limited to a simple division of the body referable to the established laws of cell-multiplication; for the assumption that the nucleus exercises a sexual function, though insisted on by some observers, does not rest on a sufficient number of continuous and connected observations.

In many cases, however, an encysting process becomes introduced into this simple form of reproduction. The organism withdraws its pseudopodia, secretes around it a membranous cyst, and passes into a resting state. Within the cyst the protoplasm divides into two or more portions, and these finally break through the walls of the cyst and become free.

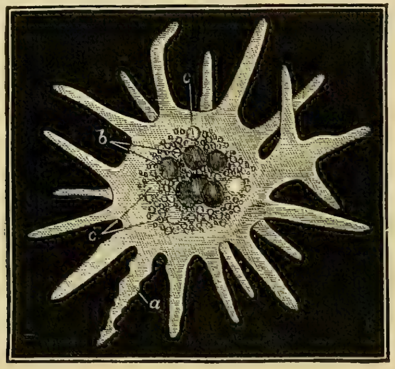
Hertwig and Lesser regard this intercalation of an encysting process into the development-cycle of the organism as conditioned by the laws of adaptation with inheritance. Many observed phenomena tend to show that the encysting at first arose from an adaptation to external conditions, and only at a subsequent period became subservient to reproduction. They suggest that it may have served originally either in maintaining the vitality of the organism during the drying up of the pools of water inhabited by it, or in affording a protection from its enemies when, after abundant ingestion of nutriment, it passes for the purposes of digestion into a quiescent state.

The organisms distinguished by the characters here enumerated, together with certain marine forms—the so-called Foraminifera—to which the present review is not intended to extend, correspond

very nearly to the *Rhizopoda* with the limits assigned to this group by Max Schultze. Hertwig and Lesser, however, substitute for the designation Rhizopoda in the Schultzian sense that of *Sarcodina,* and confine the former to one of the sections into which they have divided their group of the *Monothalamia.*

From these general remarks we may now pass to the more important special forms to which the attention of zoologists has been recently directed.

Fig. 1.



Dactylosphærium vitreum. *a,* pseudopodium in the act of withdrawal; *b,* food-pellets; *c c,* non-contractile vacuoles. (After Hertwig and Lesser.)

Under the name of *Dactylosphærium vitreum* (fig. 1), Hertwig and Lesser describe a freshwater rhizopod which but slightly differs from *Amœba.* It has a roundish body composed of homogeneous hyaline protoplasm with a multitude of yellow or green strongly refringent granules, which fill the whole of the interior of the body as far as a narrow hyaline margin. The pseudopodia are blunt finger-shaped processes which radiate in all directions from the surface, and consist of a perfectly homogeneous hyaline protoplasm.

The mode in which the pseudopodia are withdrawn is peculiar. When one of these is about to disappear, it seems suddenly to change its form; its smooth surface becomes nodular and irregularly sinuous, it conveys the impression of having suddenly lost its turgescence, and then it rapidly flows back into the body.

Numerous non-contractile vacuoles exist; but the multitude of coloured corpuscles so interfered with the transparency of the protoplasm, that it was impossible to decide with certainty as to the presence of a nucleus.

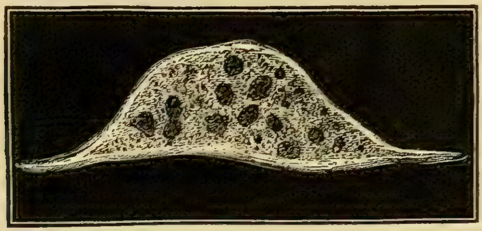
In a variety in which the yellow corpuscles are replaced by

green, the whole, or part, of the surface is seen to be in most cases covered with fine villi-like processes, a condition very similar to one which has been frequently described as occurring in *Amœba*.

Towards the centre of the protoplasm were numerous pellets composed of foreign matter, evidently the remains of nutriment derived from plants and ingested as in other amœboid organisms.

Hyalodiscus rubicundus (fig. 2) is another form described by Hertwig and Lesser. It differs from all known sarcode animals in its peculiar mode of locomotion; for while, in all other Rhizopoda, locomotion is effected by variously formed pseudopodia, by which the organism is pushed or pulled forwards, or by means of an apparent pouring forth of a stream of protoplasm, by which it, as it were, flows over the subjacent objects, in *Hyalodiscus* all parts of the surface contribute equally to the locomotion, and it is only the direction in which all the individual parts of the surface move that determines the line in which the organism glides forwards.

Fig. 2.



Hyalodiscus rubicundus. The animal in the act of creeping, viewed laterally. (After Hertwig and Lesser.)

The form of *Hyalodiscus rubicundus* is that of a disk flattened on one side, convex on the opposite. Its body consists of a homogeneous, colourless, and hyaline external layer (ectosarc), and a granular central mass (endosarc), which is loaded with brownish red corpuscles. In the middle of the endosarc is a nucleus, and towards its periphery numerous vacuoles; but whether these are or are not contractile could not be determined.

Though the *Hyalodiscus* moves with considerable velocity over the stage of the microscope, scarcely any change of shape can be observed in it—a feature in which it strongly contrasts with the protean changes of an *Amœba*. During the progression of *Hyalodiscus*

every point of the surface may, under the microscope, be seen to be in a constant rotation; so that on the dorsal side of the animal (that turned away from the supporting surface) each point travels from behind forwards, while on the ventral side it travels from before backwards, thus causing, by friction against the surface of support, a rolling forwards of the entire animal. This rotation of the superficial particles of the sarcode body is rendered apparent by watching the movements of minute foreign bodies which happen to be adherent at the surface.

It is not, however, in the external layer alone, but in the whole body, that motion of rotation exists. The coloured corpuscles and granules of the endosarc may be seen to be constantly moving in a forward direction on the dorsal side, and in the opposite direction on the ventral side, so that every one of them describes a complete circle. Even the nucleus participates in the general rotation of the particles, though from its nearly central position the circle in which it rotates is a small one.

This interesting form of protoplasm motion can be explained, as Hertwig and Lesser remark, only by attributing to every point of the body, as well as of the endosarc as of the ectosarc, a nearly uniform contractility, such as Max Schultze assumes in order to explain protoplasm-currents in general.

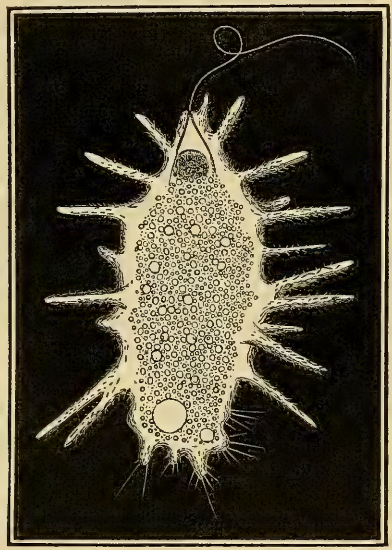
Hertwig and Lesser have not witnessed the actual ingestion of nutriment, though abundant nutriment-masses were seen imbedded in the endosarc, where they lay without being surrounded by any distinct vacuole.

A remarkable amœboid organism, which forms in some respects a transition form between the *Amœbæ* and the *Flagellata*, has, under the name of *Mastigamœba aspera* (fig. 3), been described by Franz Eilhard Schulze*, who discovered it in a pond of the Botanic Garden at Grätz. Like other amœboids it is very changeable in shape; but its usual form is that of an appressed oval, from whose sides simple, blunt, finger-shaped pseudopodia are given off. One end is more pointed than the opposite, and from the pointed end, which during locomotion is always turned forward, there projects a long, very fine, non-retractile, cylindrical filament of sarcode, in all respects resembling a flagellum of the true *Flagellata*. The regularly disposed lateral pseudopodia, and the position of the flagellum at the end of the long axis, give to the creature a superficial resemblance to a bilateral animal,

* F. E. Schulze, "Rhizopodenstudien," Arch. f. mikr. Anat. vol. xi. p. 583.

creeping by means of the appendages situated along the sides of its body.

Fig. 3.



Mastigamœba aspera, as seen when creeping over the field of the microscope. (After F. E. Schulze.)

In the body may be distinguished a strongly refringent, hyaline, colourless ectosarc, from which the pseudopodia directly proceed, and a softer endosarc loaded with clear reddish yellow spherules and colourless granules, and usually containing also the masses of ingested nutriment. The greater part of the external surface is beset with very minute, refringent, rod-like structures, compared by the author to certain *Bacteria* (*Bacteria termo*). These usually lie tangentially to the surface, to which they give a peculiar roughness, which has suggested the specific name. During the act of creeping the posterior pseudopodia are usually reduced to the condition of short thick processes, from which may be seen radiating extremely fine sarcode projections, quite like the fine processes observed on the hinder end of certain *Amœbæ* (*Amœba princeps*), where they give a kind of flocculent appearance to the surface. The endosarc at the boundary between it and the ectosarc contains one or two vacuoles, which always lie at the hinder end and alternately appear and disappear, without, however, showing any distinctly rhythmical pulsation.

At the anterior end of the animal, just below the root of the flagellum, and at the boundary between endosarc and ectosarc, there is imbedded in the endosarc a roundish, smooth, rather strongly refringent body, whose significance has not been determined. It projects beyond the boundary of the endosarc, and appears to be surrounded by a clear area, which separates it by a considerable space from the ectosarc, and by a much narrower space from the endosarc in which it is imbedded. This area is extended forward in a point reaching the surface of the body close to the root of the flagellum; but whether it communicates here with the exterior could not be determined. The body thus enclosed within the clear area shows in its interior a great number of sharply defined, spherical, clear corpuscles; and it can slowly but distinctly change its shape, appearing at one time oval, then quite spherical, then more irregular with rounded angles—characters which the author considers incompatible with the supposition of its being either a nucleus or a nucleolus, in the latter case with the surrounding clear area representing the body of the nucleus.

The liability, however, of the nucleus or nucleolus to changes of form ought not to surprise us. Hanstein has shown the occurrence of amœboid changes of form in the nucleus of a great number of plant-cells*; Alexander Brandt has demonstrated similar changes in the nucleolus of the egg in *Blatta*†; and Eimer has shown that the germinal spot (nucleolus) in the egg of the *Silurus glanis* and that of the Carp exhibits amœboid changes like those of the colourless blood-corpuscles‡.

Under the name of *Plakopus ruber* (fig. 4), F. E. Schulze § describes an amœboid rhizopod, which is rendered very remarkable by the peculiar condition of its pseudopodia. These are in the form of thin membranes, which may extend themselves over the surface of other bodies or project free into the surrounding water. They form either a single very thin plate which spreads over the supporting body, or they consist of several lamellæ which unite with

* Botanische Zeitung, 1872.

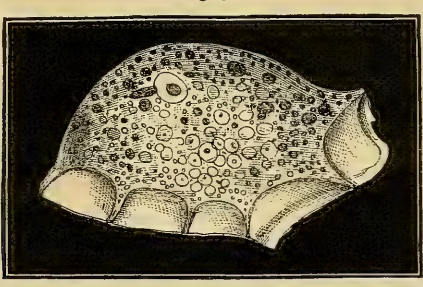
† "Ueber active Formveränderungen des Kernkörperchens," Arch. für mikr. Anat. vol. x. p. 505.

‡ "Ueber amöboide Bewegungen des Kernkörperchens," Arch. für mikr. Anat. vol. xi. 1875.

§ Arch. f. mikr. Anat. vol. xi. 1875.

one another at different angles so as to enclose funnel-shaped cavities with their mouths turned outwards.

Fig. 4.



Plakopus ruber, with its membranous pseudopodia enclosing cup-shaped cavities; multitudes of vermilion-coloured corpuscles scattered through its protoplasm. (After F. E. Schulze.)

The body is differentiated into a hyaline, refringent, cortical layer, from which the pseudopodia are formed, and an internal parenchyma in which granules, usually of a cinnabar or brick-red colour, though occasionally green, are imbedded.

The parenchyma contains also one or more nuclei, whose position changes, as in the true *Amœba*, with the movements of the animal. The nucleus encloses a relatively large nucleolus.

Finally round vacuoles in variable number and of different sizes are scattered through the parenchyma, and may sometimes be seen to have passed into the pseudopodia. Their pulsation is not always manifest.

Schulze has not succeeded in demonstrating any decided fact regarding the reproduction of this curious rhizopod.

Greeff gives the name of *Pelomyxa palustris* (fig. 5) to an amœboid organism which he discovered spreading over the bottom of stagnant pools, first in the neighbourhood of Bonn and afterwards at Marburg*. It isusually in the condition of little, slimy, blackish sarcode masses, which may attain a diameter of even two millimetres. It is capable of great change of shape during its active amœboid movements, which are effected by the extension of its periphery into thick lobes or hemispherical projections, or by continued undulations of its surface.

* Arch. f. mikr. Anat. vol. x. 1874. The name of *Pelobius*, which he had first assigned to it, had been already given to an aquatic beetle, and was therefore changed by Greeff into *Pelomyxa*.

The substance of its body is differentiated into an outer cortical layer of homogeneous hyaline sarcode and an inner parenchyma loaded with spherical vacuoles, which give it a vesicular or frothy appearance. Its dark colour is due to foreign matter taken in as nutriment; and specimens from Rostock, since described by Fr. Eil. Schulze*, were colourless.

Besides the vacuoles there occur in the parenchyma a great number of nucleus-like bodies, as well as of peculiar globular, hyaline, and brilliant bodies, to which Greeff gives the name of "Glanzkörper," and of minute rod-like structures.

The nucleus-like bodies are very numerous, some hundreds being visible in a single specimen of ordinary size. They enclose hyaline contents with minute dark granules, which lie against their walls. In some of them, instead of the minute granules, several larger bodies like nucleoli make their appearance. These increase in size, become excavated by a cavity, and finally occupy the whole interior of the apparent nucleus, which now bursts and sets them free into the surrounding parenchyma. Greeff believes that after becoming free they are transformed into the hyaline homogeneous bodies (*Glanzkörper*).

These last exist in great numbers, and give to *Pelomyxa* a very characteristic appearance. They are for the most part of a globular form, and consist of a firm glistening capsule with mostly hyaline and homogeneous contents. They multiply by division in the interior of the *Pelomyxa*. Sometimes the contents were seen to have become retracted from the wall of the capsule and to assume an amœboid outline; but Greeff was unable to follow them through further changes.

He, however, records an observation which, if it be not referable to a case of parasitism, would seem to throw light on the reproduction of *Pelomyxa*. While watching under the microscope an old and apparently dead specimen of *Pelomyxa*, he saw suddenly break forth from its surface a multitude of minute amœbiform bodies, each with a nucleus and contractile vacuole. After exhibiting for some time active amœboid movements, they became more sluggish, withdrew their pseudopodia, assumed the form of spherical or pyriform bodies, and passed into a resting state. From these a long vibratile filament was subsequently developed, and the *Amœbæ* became thus changed into active swimming Flagellates. Their further destiny Greeff did not succeed in disco-

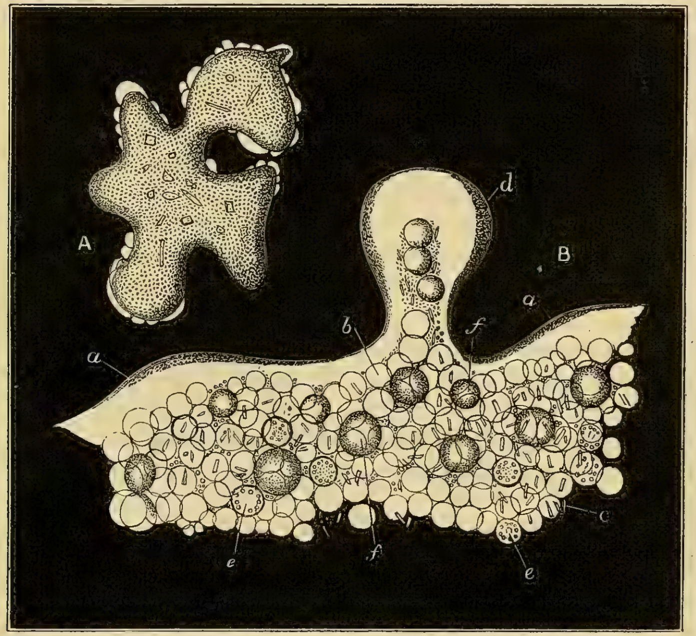
* "Rhizopodenstudien," Arch f. mikr. Anat. vol. xi.

vering; but he believes that the amœboid brood is directly derived from the hyaline bodies, which he regards as the germs or spores of the *Pelomyxa*.

The only form of reproduction observed by F. E. Schulze in *Pelomyxa* was a division of the whole body*.

The rods are scattered in great numbers in the parenchyma. They are composed of an organic substance; but Greeff was not able to determine any thing as to their origin or significance.

Fig. 5.



Pelomyxa palustris. A, the entire rhizopod as it appears when in active amœboid motion. B, a portion more highly magnified: *a a*, the hyaline ectosarc thrown into prominent undulations; *b*, one of the vacuoles of the endosarc; *d*, protruded mass of the hyaline ectosarc; *e e*, nuclei; *f f*, globular hyaline homogeneous bodies (*Glanzkörper*). Numerous rod-like bodies (*c*) are seen scattered through the endosarc. (After Greeff.)

We owe to Greeff some very interesting observations showing that the *Amœbæ*, a group of organisms which had been hitherto sup-

* F. E. Schulze, *loc. cit.*

posed to be exclusively aquatic, have terrestrial representatives*. The *Amœba terricola* of Greeff occurs in earth and dry sand. It has an irregularly spherical form, with blunt nodular projections and a dull glassy appearance. It looks like an irregularly shaped fragment of silica, and might be easily passed by as a grain of sand.

A more careful examination shows within it yellow granules, which are in lively motion, streaming here and there through the soft protoplasm.

Its body is composed of two substances, an outer hyaline layer of firmer, consistence, and an inner granular, softer, and more fluid parenchyma. Nowhere among the aquatic *Amœbæ* is the difference between these two constituents so strongly defined as here. The hyaline outer layer is the chief source of the contractility.

The motions of the animal are peculiar and different from those of the aquatic *Amœbæ*. It does not, like these, appear to flow over the surface on which it lies, but raises itself on the projections from its body, which, unlike the pseudopodia of the aquatic *Amœbæ*, are firm and strong enough to support it. While thus balanced, the influx of the granular parenchyma towards certain parts of the periphery disturbs the equilibrium and causes the whole to roll over. Its motion is thus a rolling instead of a creeping one. In some cases the peculiar villous condition first noticed by Wallich and Carter in certain aquatic *Amœbæ* was present on the posterior end of the body.

No special membrane is to be found on the outer layer; and Greeff, in opposition to Auerbach, denies the presence of such a membrane, not merely on his terrestrial *Amœba*, but on the aquatic ones.

A number of clear vacuoles of different sizes may be seen floating in the soft parenchyma. These are very variable in size and number. They are carried about by the currents, and may be seen in one and the same individual to change from minute to minute. When two vacuoles come in contact they frequently run together into a single one, which may still further combine with others. Occasionally one of the large vacuoles may be seen to approach the periphery of the parenchyma and then suddenly disappear as if it had been emptied outwards. After a few seconds, however, we find in its place a great number of very small vacuoles, which again gradually unite with one another until, instead of a

* "Ueber einige in der Erde lebenden Amœben" &c., Arch. f. mikr. Anat. vol. ii. 1866.

multitude of small vacuoles, we have once more a single large one.

Small algæ, diatoms, and other foreign bodies are also found imbedded in the parenchyma. These have been taken in as nutriment, and are frequently found enveloped by the yellow bodies already referred to. Greeff regards these yellow bodies, which are also frequently present in the aquatic *Amœbæ*, as intended to promote the digestion of the ingested nutriment; and he compares them with the so-called liver-cells, also of a yellowish colour, which clothe the digestive canal in many of the lower animals—an analogy which at best may be regarded as very remote.

Among the contents of the body occur also minute crystalline-looking structures, which, however, are without any definite form. Greeff has no doubt that they are a product of the *Amœba* itself, and not introduced from without. Similar bodies are known to occur in aquatic *Amœbæ* and other Rhizopoda, where they have been described by Auerbach, Wallich, Carter, and others.

But the most important structure found in the inner parenchyma is the nucleus. Like many of the other bodies which are found there, it is carried about by the sarcode currents, and is so soft that it changes its shape when it meets with any obstruction in its course. It is enveloped in a double membrane. It is viewed by Greeff as an organ of reproduction. It consists at first of a homogeneous protoplasm with some dark glistening granules; but after a time the entire nucleus becomes filled with solid round corpuscles, which he regards as the young progeny of the *Amœba*. The outer covering then disappears, and he believes that the solid corpuscles escape into the surrounding parenchyma. The whole of the nucleus thus becomes broken up into the young brood which fills the body of the *Amœba*. The *Amœba* now ceases to take in food, its motions become less active, and its functions seem to be entirely confined to the protection and development of the young. These are soon ejected, and become developed externally into the form of the parent. Greeff has found such young *Amœbæ* in the surrounding sand.

In two instances Greeff observed in the interior of the body elongated soft masses apparently composed of bundles of sinuous hair-like filaments, which recalled the supposed spermatic filaments described by Balbiani in the so-called nucleolus of the Infusoria;

but his observations were not sufficiently complete to justify him in maintaining their actual analogy with these bodies.

In connexion with Greeff's observations on the relations of the nucleus to reproduction in *Amœba terricola*, may be here mentioned those of Fr. Eil. Schulze on the behaviour of this body in the multiplication of *A. polypodia*, Max Schultze. F. E. Schulze* has seen the nucleus with its nucleolus in this rhizopod divide by a transverse constriction; the two halves recede from one another, and the body of the *Amœba* then, by a similar constriction, divides between the two segments of the original nucleus. The process in this case thus differs essentially from that described by Greeff, and corresponds to a well-known form of cell-multiplication.

The *Amœba terricola* occurs, according to Greeff, very frequently in sand and in the earth on the root-fibres of mosses, grasses, and other plants when they do not form too thick a layer on the surface of rocks, walls, house-tops, trunks of trees, and the like. It is almost always found in company with terrestrial Arctiscoida (" bear animalcules "), Rotifers, Anguillulæ, &c.

The shallow layer of earth in which it lives frequently exposes it to desiccation, when its vital activity is arrested. In this condition the firm hyaline outer layer contracts more and more with the increasing dryness, and thus affords to the soft granular parenchyma a protection against absolute desiccation. When moistened, however, with water, it once more awakens to complete activity even after a dormancy of many months.

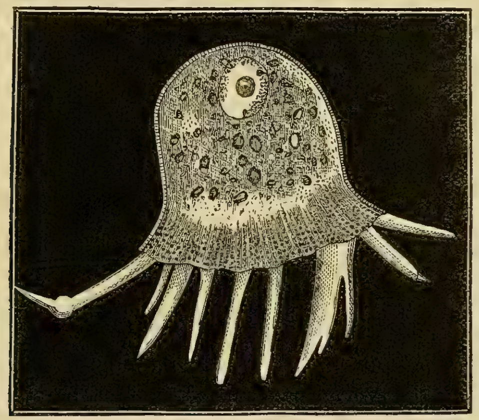
Among the terrestrial amœbiform organisms discovered by Greeff is one which he assigns to a new genus under the name of *Amphizonella*. He distinguishes three species, of which one, *A. violacea*, has been especially observed by him. The *Amphizonellæ* are distinguished from the *Amœbæ* by being provided with an external soft capsule, which is quite distinct from the proper cortical layer. They have a large round nucleus; and pseudopodia, which rapidly appear and disappear, are emitted from the interior and bore their way through the external capsule, which again, on their withdrawal, becomes so completely closed as to lose all trace of having been perforated. In *A. violacea* the internal protoplasm is of a beautiful violet colour. Greeff has witnessed a partial fusion of two individuals. He regards this as a case of conjugation, and believes that it is followed by the formation of a young brood within the body of the parents.

* Arch. f. mikr. Anat. vol. xi. p. 592.

Some other forms have been described by Archer* as species of *Amphizonella*, but which, unlike the terrestrial species discovered by Greeff, are inhabitants of fresh water. The *A. vestita* of Archer, however, is, as shown by Hertwig and Lesser, not referable to Greeff's *Amphizonella*, and is regarded by these observers as identical with their own *Cochliopodium pellucidum*. They rectify Archer's description, and point out the causes of error by which he was deceived in his attempts at identification.

The complete disappearance in the different species of *Amphizonella* of the apertures caused by the pseudopodia in boring their way through the outer coat reminds us vividly of the phenomena which have been proved to accompany the migration of the blood-corpuscles through the coats of the capillaries in the higher animals.

Fig. 6.



Cochliopodium pellucidum, viewed from the side, with widely open test-orifice, through which numerous pseudopodia are projected. (After F. E. Schulze.)

Hertwig and Lesser† describe, under the name of *Cochliopodium pellucidum* (fig. 6), a very interesting Rhizopod which they found in great quantity in ditches at Reinhardsbrunnen and in a pond in the Botanic Gardens at Bonn. They have identified it with Archer's spineless variety of *Amphizonella vestita*, which they regard as having nothing which would justify a subordination of it to Greeff's genus *Amphizonella*.

It consists of a nucleus-bearing protoplasm body which, not-

* Quart. Journ. Micr. Sci. vol. xi. 1871. † *Loc. cit.*

withstanding its being enveloped in a closely applied test, is subjected to all the protean changes of form which are so characteristic of the naked sarcode animals.

The test is quite colourless, and possesses an areolar structure like that of the shell of *Arcella*, from which, however, it differs in its much greater delicacy and in its flexibility and want of definite form. It possesses great extensibility and elasticity, and becomes dilated or contracted in accordance with the form assumed by the contained protoplasm. It has a single opening through which the pseudopodia are protruded, and whose diameter varies with the condition of the protoplasm; but whose position is constant with regard to the nucleus, which always lies opposite to it in the fundus of the test. Besides this opening, the test is quite imperforate; and Archer was deceived in supposing that pseudopodia were emitted through orifices in its sides.

The contractile vesicles which occur along with simple, frequently very numerous, non-contractile vacuoles, lie quite in the periphery of the sarcode, and when in a state of diastole carry outward for a slight distance the part of the test which lies immediately over them.

The pseudopodia are conical and hyaline. During progression the pseudopodial opening is dilated, and the body extends itself more or less over the subjacent surface, forming with its shortened pseudopodia a kind of flattened foot on which the whole organism glides forward. It is this mode of progression, compared by the authors to that of a gasteropod, which has suggested the name of *Cochliopodium*.

The relations of *Cochliopodium* to the Monothalamia of Hertwig and Lesser cannot be overlooked, while among these the structure of its test point out *Arcella* as its nearest ally. Perhaps, as Hertwig and Lesser remark, a continued study will render possible a union of *Cochliopodium* with *Arcella*; but in the mean time it is better to regard the two genera as distinct, and to abstain from placing *Cochliopodium* among the Monothalamia, from which it is separated by its great inconstancy of body-form.

Cochliopodium pellucidum has also been examined by F. E. Schulze *, who confirms in all essential points the description given by Hertwig and Lesser.

A terrestrial *Arcella*, which bears a considerable resemblance to

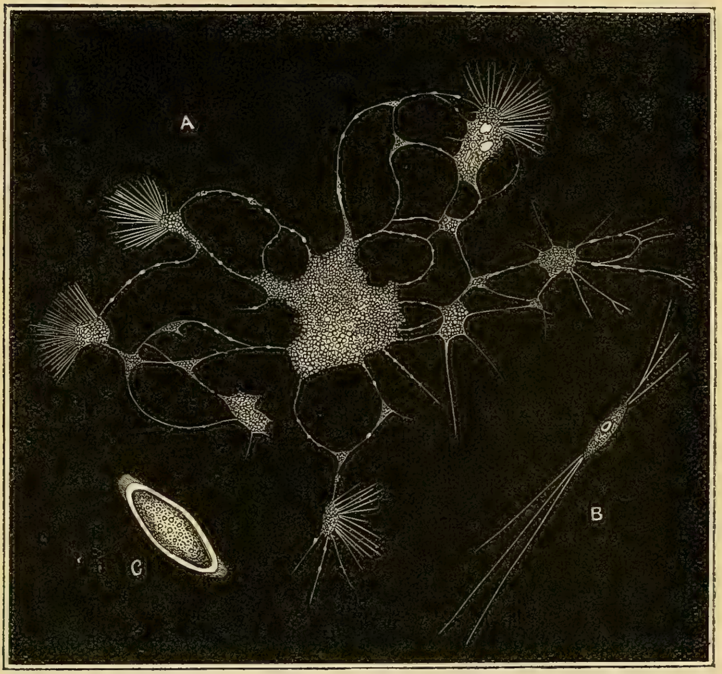
* F. E. Schulze, "Rhizopodenstudien," Arch. für mikr. Anat. vol. xi. p. 337, 1875.

the aquatic *A. vulgaris*, to be referred to in the sequel, has also been discovered by Greeff. He names it *A. arenaria.*

To Cienkowski we are indebted for the discovery and investigation of another very simple sarcodic organism to which he has given the name of *Labyrinthulea**.

He found it among the lower algæ which cover the piles in the harbour of Odessa, where it is represented by two species, which he names *L. vitellina* (fig. 7 A) and *L. macrocystis* (fig. 7 B, C).

Fig. 7.



Labyrinthulea vitellina. A. The entire organism, with the fusiform bodies wandering over the filamentary network. B. One of the fusiform bodies of *L. macrocystis* still further magnified, showing its nucleus with nucleolus. C. The same, entering into the resting stage. (After Cienkowski.)

It consists of a central mass of sarcode from which are given off thread-like prolongations which divide and subdivide and inosculate with one another, forming a net-like or dendritic ex-

* "Ueber den Bau und die Entwickl. der Labyrinthulen," Arch. f. mikr. Anat. vol. iii. 1867.

pansion, which in its ultimate ramifications consists of filaments of extreme tenuity. On this complicated plexus may be noticed in constant motion peculiar spindle-shaped bodies which, in *L. vitellina*, are of an orange-red colour, and which glide in all directions along the course of the filaments.

The central mass consists of a multitude of little sarcode spherules, the whole being held together by a soft, finely granular substance, which at the periphery forms a thin enveloping layer. Small aggregates of a similar sarcode occur also on various parts of the filamentary network, where, however, they are not held together by a cortical layer, as in the great central mass. From these smaller aggregates there also run in various directions branching and anastomosing filaments, along which the orange-red spindles glide.

Cienkowski has shown the identity of the moving spindles with the spherules of the central mass. He has seen these spherules become fusiform at the periphery of this mass and then leave it in order to wander along the course of the filaments.

After several hours it will be seen that the greater part of the spherules have assumed the spindle shape, and, abandoning the central sarcode, have entered the filaments and wandered to the margin of the plexus.

The spindles are little masses of protoplasm destitute of a membrane and very mutable in form. Each encloses a nucleus with nucleolus, and multiplies by division. They are therefore true membraneless cells. They exhibit no motion, except in the paths formed for them by the branching filaments.

Cienkowski describes the filamentary tracts along which the spindles wander as destitute of contractility, showing no motion, and never projecting pseudopodia. He regards the whole plexus as a rigid non-mobile structure, and believes that its component filaments never become fused together, but only touch one another and adhere. He has, moreover, followed its formation, and from a piece of the central protoplasm showing at first no trace of the filaments, he has seen a complicated plexus developed in the course of a few hours. He regards it as a gelatino-fibrous excretion of the spindles.

If this be a correct view of the nature of the plexus, it is obvious that the cause of the motion is to be sought for in the spindles themselves, and not in the paths over which they wander. This, however, is scarcely in accordance with the known pheno-

mena presented by protoplasmic organisms in general; and we should be more disposed to believe that the filaments are truly sarcodic and contractile, and that the spindles travel along them as foreign particles travel along the pseudopodia of other species. This is certainly the case in the closely allied *Chlamidomyxis labyrinthuloides* of Archer; and in our efforts to discover the true nature of the phenomenon in *Labyrinthulea*, the analogy of this curious organism can scarcely be ignored.

In *Labyrinthulea macrocystis* Cienkowski has observed the passing of the organism into the resting state. The first indication of this consists in the fact that the cells, whether those which are contained in the central mass or those which wander along the filaments, attain a considerable size and become richer in granules and darker in colour. The spindle-shaped cells gradually assume an oval shape, while each has its surface hardened into a membrane, and the whole becomes surrounded by a common, smooth, thick investment. In this way all the cells of the colony, cemented by a common cortical substance into a globular or vermiform mass, remain for many weeks unchanged.

After these aggregations of cysts had remained in sea-water for about six weeks, the contents of each cyst were observed to have become divided into four parts, the cyst-envelope at the same time becoming very soft and finally disappearing, so as to allow the four divisions to escape as free moving spherules. Soon after this the *Labyrinthulea*-cells with their accompanying filaments had made their appearance. He has not actually seen the change of the liberated spherules into the *Labyrinthulea*-cells, but he has no doubt of its reality.

Mr. Archer, of Dublin, has described, with excellent figures, a very remarkable organism which in many respects possesses intimate relations with Cienkowski's *Labyrinthulea*. He found it in fresh water, and named it *Chlamidomyxis labyrinthuloides** (fig. 8).

It has a soft sarcodic body surrounded by an outer tough cyst, which is of a very irregular outline, is composed of many layers, and shows distinct cellulose reaction.

The sarcode contents are composed of a basic hyaline substance, in which are immersed various kinds of granules. Among these are certain homogeneous rounded corpuscles of a pale bluish tint, which, as we shall presently see, take an important part in the

* "On *Chlamidomyxis labyrinthuloides*," Quart. Journ. Micr. Soc. vol. xv.

vital phenomena of the organism. Notwithstanding the toughness of the cyst, the contents can burst their way through it, and the protoplasm then pours forth, carrying with it its imbedded granules, and spreading itself out over the field of the microscope. It now shows a beautiful play of very numerous globular pulsatile vacuoles.

The first part of the protoplasm which issues from the cyst

Fig. 8.

Chlamidomyxis labyrinthuloides. The protoplasm pouring itself out of the cyst, and the fusiform bodies travelling in all directions over the filamentary plexus. *a a*, isolated masses of protoplasm showing themselves in the filamentary plexus; *b*, a navicula seized for ingestion and about to be carried into the main mass of protoplasm. (After Archer.)

forms a main trunk, which soon subdivides into branches from which others are emitted; and in a short time we see a complex system of ramifications extending far and wide, and formed by hyaline, quite colourless threads of extreme tenuity.

At the same time there appear in these threads minute fusiform bodies of a pale bluish colour, which may be seen to be in constant motion along them. They are identical with the round bluish granules of the central mass; and it is only on leaving this to wander along the filaments that they assume the fusiform shape.

Archer has found no nuclei in any part of his *Chlamidomyxis*, either in the central protoplasm or in the moving spindles. Foreign bodies which had been ingested as nutriment were not unfrequent in the protoplasm of even the completely encysted organism. The whole of the protruded protoplasm can again withdraw itself into the cyst, and then, by the excretion of a wall, shut itself completely in.

The only thing which he has seen bearing any evidence of a reproductive process is a subdivision of the contents of the cyst into globular masses, which, at first naked, become afterwards invested by a special membrane.

From Archer's observations it would seem that *Chlamidomyxis* originates parasitically in the cells of *Sphagnum* and other water-plants, and that it afterwards quits the cavity of the cell and becomes external.

It is plain that in *Chlamidomyxis* we have a form very closely allied to *Labyrinthulea*. From this it differs in possessing an external, laminated, cellulose cyst, which appears to be constant, and not, as in many other low sarcoid organisms, confined to a resting-period in the cycle of development. The absence of nuclei in the fusiform bodies is another difference of importance. But the most important point in which *Chlamidomyxis* differs from *Labyrinthulea*, as described by Cienkowski, is found in the nature of the filamentary plexus which forms the paths along which the fusiform bodies perform their strange wanderings. This, instead of being formed of a rigid non-vitalized excretion, as is maintained by Cienkowski to be the case in *Labyrinthulea*, is shown by the observations of Archer to form in *Chlamidomyxis* a contractile net of living protoplasm; and the motions of the fusiform bodies along the filaments, which was so difficult to explain in *Labyrinthulea*, will be easily understood in *Chlamidomyxis*, where it is obviously

referable to the contraction of the protoplasmic network. It is here comparable to the well-known granule-currents in sarcode filaments. One can hardly help believing, however, that the real nature of the filamentary network in *Labyrinthulea* has been misunderstood by Cienkowski, and that in this, as well as in *Chlamidomyxis*, it constitutes a true protoplasm-net.

The long-known "sun animalcule," *Actinophrys sol*, has recently been studied by Hertwig and Lesser *. These excellent observers have especially attended to that part of its structure which was maintained by Grenacher to correspond to the central capsule of the Radiolaria, and have shown it to be a large nucleus with nucleolus, as, indeed, Stein had already maintained to be the true import of this body in *A. oculata*, a closely allied marine form.

The researches of Hertwig and Lesser have now left no uncertainty regarding the structure of this most interesting little Rhizopod, so that a definition more exact than any hitherto attempted can be given of it. The true conception of *A. sol* would be thus, according to these observers, that of a spherical Rhizopod with the protoplasm forming its central part homogeneous and that of its peripheral part vesicular. In its peripheral portion is a single contractile vacuole, which projects far beyond the surface. In the centre of the body is the nucleus with a distinct membrane and large nucleolus. The pseudopodia, which radiate in all directions from the surface, are provided with an axis-filament; they are loaded with granules, seldom anastomose, and never branch.

The union of numerous individuals of *A. sol* into a single mass has often been observed. The number thus fused together is variable and has been estimated at from two to nine; and the fusion is so intimate that it is impossible to demonstrate the boundaries of the component individuals, the compound mass appearing as a single *Actinophrys*. The nuclei, however, remain distinct, and give evidence of the composition. The tendency to combine shows itself also in the pseudopodia, which, in the compound masses, exhibit numerous anastomoses with one another.

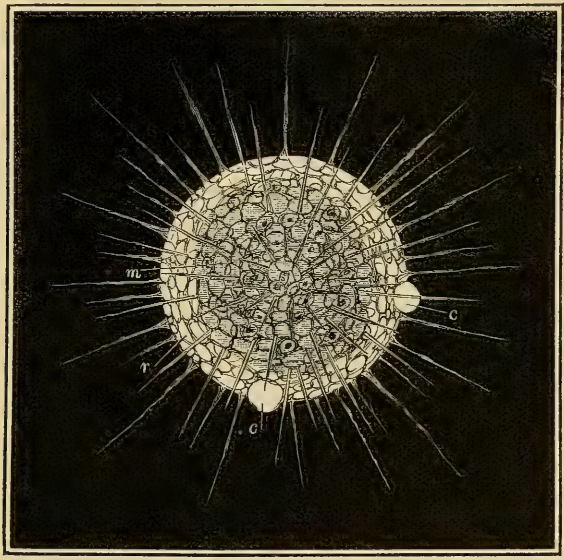
The individuals which have thus become amalgamated may separate from one another and then become once more united into a common mass.

It is not at all likely that this phenomenon of conjugation has any thing to do with a truly sexual differentiation; nor can we, indeed,

* *Loc. cit.*

discover in it any important bearing on the life-history of the animal: as a manifestation, however, of the properties of living protoplasm it is full of significance.

Fig. 9.



Actinosphærium Eichhornii. General view of the entire Rhizopod. *m*, medullary region (endosarc); *r*, cortical region (ectosarc); *c c*, contractile vacuoles. (After Hertwig and Lesser.)

Franz Eilhard Schulze* has made some interesting observations on the structure and development of *Actinosphærium Eichhornii* (figs. 9 and 10), which had been generally confounded with *Actinophrys sol*, until Stein † insisted on the value of the differences between them, and separated the two as distinct genera.

The most important steps, however, in our knowledge of this fine Rhizopod had already been made by Kölliker‡ and by Max Schultze§. Kölliker had drawn attention to the peculiar vesicular or "alveolar" structure of its sarcode, and to the differentiation of this into two regions—a more opaque central or medullary region (endosarc), and a clearer peripheral or cortical region (ectosarc); while he showed that numerous nuclei were included in

* "Rhizopodenstudien," Arch. f. mikr. Anat. vol. x. 1874.

† Abhandl. der böhmischen Akademie der Wissensch. 1857.

‡ Zeitschr. f. wissensch. Zool. vol. i. 1849.

§ Das Protoplasma der Rhizopoden u. der Pflanzenzellen, 1863.

the central mass. Max Schultze had further made the important discovery that the pseudopodia of *Actinosphærium* possess a more complex structure than had been imagined—that they consist of a firmer hyaline strongly refringent axis, surrounded by a soft, granular, mobile layer, in which alone the protoplasmic granule-streams exist. The axis was followed by him through the clear cortical zone of the Rhizopod, as far as the boundary of the darker medullary region, while the soft sarcode by which the axis is surrounded was shown to be a continuation of the cortical zone of the body.

F. E. Schulze now gives his support to the essential points of an observation made by Greeff, and maintains with that author that the axis filament of the pseudopodia is not simply a continuation of the central sarcode, but that it consists of a firm albuminous "spine," which, passing through the superficial zone, rests upon the periphery of the central sphere by a wedge-shaped extremity.

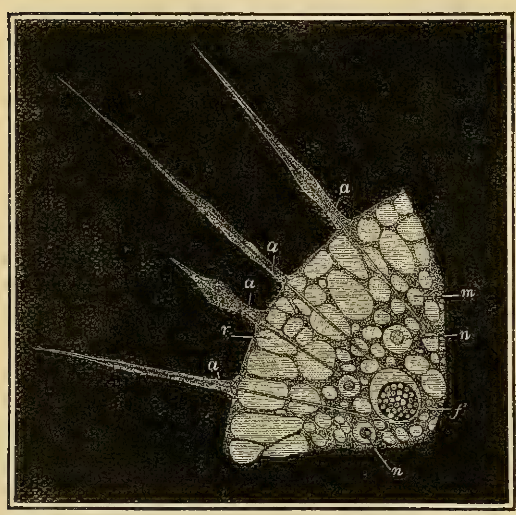
In his observations on the development of *Actinosphærium*, Schulze has been preceded and, to some extent anticipated, by Cienkowski* and by Schneider†. Schulze records the following phenomena as characterizing the reproductive process in this Rhizopod. The medullary region becomes darker, more condensed, and more sharply separated from the cortical region; the axes of the pseudopodia become indistinct and finally disappear, and the whole of the pseudopodia are withdrawn. The entire animal becomes now enveloped in a clear gelatinous excretion, and within this the body, by a process of binary segmentation, becomes broken up into a multitude of spherical masses, each with its medullary and cortical regions, but in which no distinct alveolar condition is any longer apparent. In each there is a single central nucleus, and the cortical layer, as had been already shown by Schneider, now becomes converted into a firm investment by the deposit of siliceous particles.

After remaining in this state unchanged during the whole of the winter months, the germs were observed at the beginning of spring to have lost their siliceous covering and to have become converted into minute *Actinosphæriæ*, most of which contained as yet only a single nucleus. With the growth of the young *Actinosphæria* the nuclei became multiplied and arranged themselves towards the periphery of the medullary region as in the adult animal, thus closing the cycle of development.

* Archiv f. mikr. Anat. vol. i. p. 229.

† "Zur Kenntniss der Radiolarien," Zeit. f. w. Zool. Bd. xxi. p. 507.

Fig. 10.



Actinosphærium Eichhornii. Optical section through a part of the margin. *m*, endosarc; *r*, ectosarc; *a a a*, pseudopodia, the axis filament passing through the ectosarc into the endosarc; *n n*, nucleus with nucleolus; *f*, an ingested food-mass. (After Hertwig and Lesser.)

The fusion of two or more fully developed individuals, as in *Actinophrys*, has also been frequently observed in *Actinosphærium*.

Actinophrys and *Actinosphærium* had been united by Haeckel into a small group, to which he assigns the name of *Heliozoa*. Since then, however, their structure has been found to be far more widely represented than had been imagined by Haeckel; and the Heliozoa have received large additions from certain rhizopodal forms occurring chiefly in fresh water. These have been mostly referred by their discoverers to the Radiolaria, which many of them resemble in external form. Their affinities, however, are undoubtedly with *Actinophrys* and *Actinosphærium*, and their systematic place is among the Heliozoa. The establishment of this group thus constitutes an important step in the systematic zoology of sarcodic organisms.

We are indebted to several recent observers, and more especially to Greeff, Archer, F. E. Schulze, Focke, and Hertwig and Lesser, for a long series of interesting researches on these Radiolaria-like organisms of fresh water. The discovery of freshwater forms resembling the true Radiolaria, which have been hitherto known

only as inhabitants of the sea, has for some years been rewarding the researches of several investigators of the lower forms of life.

It is to be regretted, however, that their descriptions are in many instances very contradictory, and often differ from one another so much as to render it difficult to find in them grounds for a satisfactory conclusion regarding the true structure of the organism which forms the subject of investigation *.

There can be no doubt, as has just been said, that the affinities between these freshwater organisms and the true Radiolaria have been exaggerated. Hertwig and Lesser, in their valuable memoir †, already frequently referred to, enter fully into the question of the relation between these Radiolaria-like organisms and the true Radiolaria, and arrive at the conviction that there is no close affinity between them, and that the proper allies of the freshwater forms are the long-known "sun-animalcules" *Actinophrys* and *Actinosphærium*, with which they accordingly associate them in the natural group of the Heliozoa.

In order to aid us in forming an accurate judgment on this question, it may be well to bring together here the more important characters of the true Radiolaria. From the researches of Huxley, and more especially of Johannes Müller and of Haeckel, we are now well acquainted with the structure of certain minute organisms known to the popular observer chiefly by the beautiful little siliceous shells which Ehrenberg had described under the name of *Polycystina*, and which, with their allied forms, constitute a well-defined zoological group. To this group Müller has assigned the name of *Radiolaria.* It consists of minute, sarcodic, more or less spheroidal organisms, which are usually provided with beautifully symmetrical siliceous skeletons, either in the form of perforated cases or of radiating spines, and whose body presents two concentric zones, the inner separated from the outer by a chitinous capsule ("central capsule"), and composed of numerous true nucleated cells. In almost every instance peculiar cells are also found imbedded in the sarcode which forms the outer or extracapsular zone. These cells contain a yellow pigment, and constitute the so-called "yellow cells."

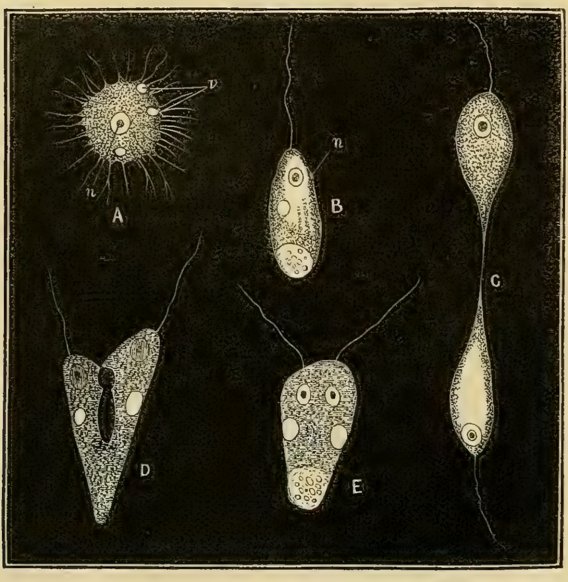
* Since the reading of the present Address an excellent *résumé* of recent researches among the Heliozoa and other rhizopodal forms, with valuable critical remarks, has been published by Mr. Archer. See 'Quart. Journ. of Micr. Sci.' for July and October 1876 and January 1877.

† "Ueber Rhizopoden u. denselben nahestehende Organismen," Archiv f. mikr. Anat., Band x. Suppl. Heft 1874.

If these characters be borne in mind, we shall have no difficulty in determining how far the freshwater organisms now about to be mentioned admit of a comparison with the true Radiolaria.

Among these freshwater Rhizopods the form which comes nearest to *Actinophrys* and *Actinosphærium*, and hence to the typical Heliozoa, is that of *Ciliophrys* (fig. 11). Under this name Cienkowski has described a new genus of heliozoal Rhizopods, represented by a single species, *C. infusionum*, which he finds common in the scum of long-standing infusions, and on which he made some important observations, showing that the swarm-spore enters into its development-cycle*. It is thus, if we except a fragmentary observation by Archer on what he regards as a large green variety

Fig. 11.



Ciliophrys infusionum. A, the *Ciliophrys* in its developed condition; *v*, contractile vacuoles; *n*, nucleus. B, the swarm-spore into which the *Ciliophrys* has become converted. C, the *Ciliophrys* in the act of self-division; each half has become converted into a swarm-spore. D, the two swarm-spores of C becoming fused into one another. E, the fusion further advanced. (After Cienkowski.)

* "Ueber einige Rhizopoden und verwandte Organismen," Arch. fur mikr. Anat. vol. xii. 1876.

of *Actinophrys sol*, the only naked heliozoan in which swarm-spore formation has been seen.

It has quite the habit of *Actinophrys sol*, except in being much smaller; and it also agrees with it in most points of structure. It has, however, one to three very small contractile vacuoles instead of the single large vacuole which in *Actinophrys* becomes, during the diastole, protruded like a bubble from the surface of the body.

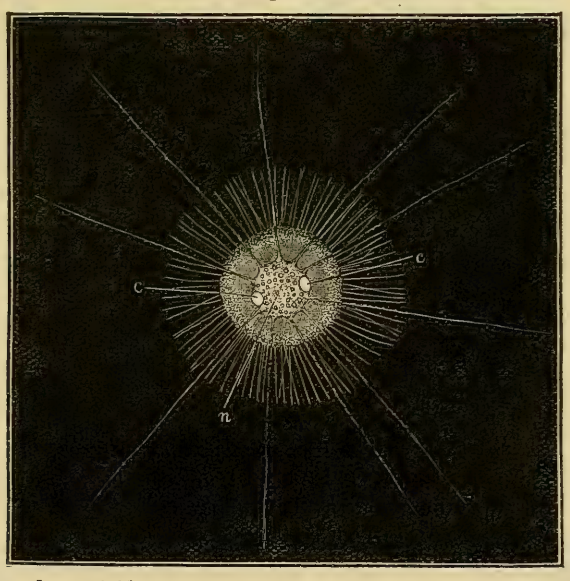
Its reproduction has been observed by Cienkowski, who finds this to be connected with a true swarm-spore formation; but instead of the locomotive germs being, as in other cases, thrown off in large numbers, it is a remarkable fact that the whole body changes into an oviform swarm-spore, with one or two cilia.

This change is preceded by the originally coarsely granular protoplasm becoming gradually homogeneous and the nucleus more conspicuous. In the meantime the pseudopodia disappear, the body assumes an oval form, and the nucleus changes its position, passing from the centre towards one end. On this end we soon perceive one or two cilia, by whose vibration the swarm-spore, now completed, is carried away through the surrounding water. Cienkowski, however, has not been able to follow the swarm-spore through any further phases.

Ciliophrys, like *Actinophrys sol*, also multiplies by constricting off portions of its body; and, like *Actinophrys*, two or more individuals may unite and fuse together into a simple mass. It is not only the fully developed *Ciliophrys* which possesses this property; for two swarm-spores may also fuse with one another. He observed a *Ciliophrys* dividing by constriction, when each half became changed into a swarm-spore. These had already retracted their pseudopodia and had developed cilia on their free ends, but still remained at the opposite ends united to one another by a narrow bridge. The connecting bridge now became suddenly bent so as to bring the sides of the two swarm-spores into contact and allow them to fuse together, forming a single two-lobed body, each lobe carrying its cilium and containing within it a nucleus. The fusion became more intimate, and the bilobed body gave place to one of a triangular form, on whose flattened base were still to be seen the cilia and, in its interior, the two cell-nuclei. Its rapid motion prevented his following its further changes; and he is unable to form any conclusions as to the real significance of the conjugation or the ultimate destiny of the swarm-spores.

Besides the truly naked Heliozoa, represented by *Actinophrys*, *Ciliophrys*, and *Actinosphærium*, a large number of others have been discovered, which, as shown by Archer, are enveloped in a soft outer investment, which he describes as an outer sarcode zone, and which may be either entirely destitute of hard parts, or which may have immersed in it hard skeletal parts, chiefly in the form of spines or spicula. The chlorophyl and other coloured granules which are frequently present in the inner body mass are never developed in this outer zone; and it is in the inner body that the pseudopodia always have their origin, merely passing through the outer zone on their way to the surrounding water. Whether this zone, however, is to be regarded as a true sarcode layer is extremely doubtful. It is, at all events, quite distinct from the proper ectosarc which it surrounds, and is probably only an excretion from this, comparable to the gelatinous excretion which is poured out on the surface of many of the lower Algæ. Hertwig and Lesser go so far as to deny its existence, and refer the appearance of an outer sarcode-like zone to an entanglement of needles and spines, even in those cases where Archer refuses to

Fig. 12.



Heterophrys spinifera. *c c*, contractile vacuoles; *n*, central dark body (endosarc or nucleus). (After Hertwig and Lesser.)

admit the presence of hard skeletal structures. The evidence, however, appears to me to be against the view thus taken by the German microscopists.

Among the forms described by Archer as developing no hard parts in the outer zone is the genus *Heterophrys*, Archer (fig. 12). In this there is a central spherical body-mass differentiated into endosarc and ectosarc, having in the endosarc a single nucleus, and in the ectosarc contractile vacuoles. The investing zone is traversed by long, granular, unbranched and non-anastomosing pseudopodia, and its periphery is extended into radiating processes of various length and fineness in the different species. These processes are regarded by Archer as simple extensions of the surface of the investing layer, which he believes to be entirely destitute of hard parts, while Hertwig and Lesser regard them as spines, and accordingly place the genus *Heterophrys* among their *Heliozoa skeletophora*.

Between such able observers it is difficult to decide; but it appears to me that the weight of evidence is in favour of Archer's interpretation, and that *Heterophrys* has no hard parts which can be regarded as constituting a skeleton like that in the true skeletophorous Heliozoa.

The enveloping zone has the appearance of being separated from the proper body by a narrow clear interval. This, as maintained by Archer, is probably only an inner layer of the zone more homogeneous and pellucid than the rest.

In *H. myriopoda*, Archer, the ectosarc of the spherical body-mass contains a dense layer of chlorophyl granules which lies just beneath its surface.

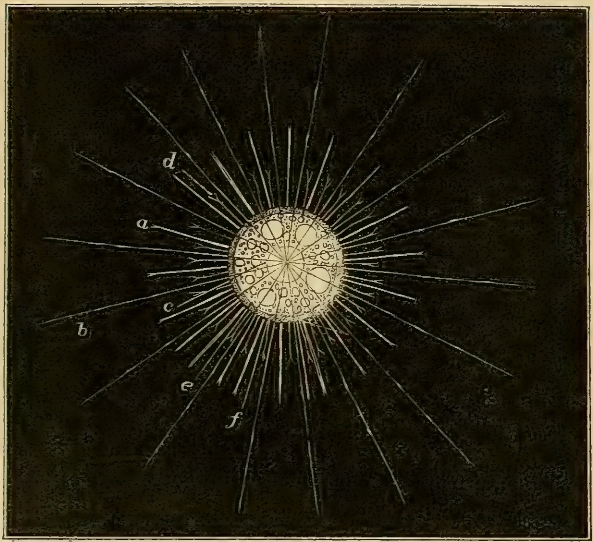
Among Heliozoa with well-developed skeleton must be mentioned the species of *Acanthocystis*. The genus *Acanthocystis* had been founded by Carter on the *Actinophrys viridis* of Ehrenberg; and what he regards as a second species of this genus has been described by him under the name of *Acanthocystis turfacea* (fig. 13). This is a beautiful little green rhizopod, which occurs in moor-pools; and Greeff now gives us the results of some further careful observations he had made on it *.

From the surface of its spherical body, which is filled with green granules, and contains a great number of vacuoles and certain

* "Ueber Radiolarien &c. des süssen Wassers," Archiv f. mikr. Anat. v. 1869. Both Greeff and Grenacher regard *A. turfacea*, Carter, as identical with the *Actinophrys viridis* of Ehrenberg; but the correctness of this determination is not admitted by Archer or by Hertwig and Lesser.

pale glistening homogeneous spherules, there radiate needle-shaped processes like the spines of an *Echinus*; and between these are emitted long slender pseudopodia. The spines are composed of silica; and each forms at its proximal end a disk-like foot. These basal disks constitute by their approximation a nearly closed siliceous capsule, by which the body is surrounded. The bases of the spines appear to be immersed in a soft sarcode-

Fig. 13.



Acanthocystis turfacea, as seen in optical section through the centre. *c*, vesicle-like space, from whose central corpuscle fine filaments are seen radiating; *b*, pseudopodium; *e*, proper body-mass, consisting of a granular protoplasm with green and pale corpuscles and enclosing numerous vacuoles; *f*, external narrow clear zone; *a*, one of the long radiating spines; *d*, one of the short spines. (After Greeff.)

like substance, which would seem also to intervene between the basal plates and the proper body of the *Acanthocystis*, which becomes thus surrounded by an external clear zone. The pseudopodia possess a firmer axis-filament and a more mobile cortical layer. Greeff states that he has seen the surface open here and there and allow the exit of strong protoplasm-streams, and again completely close, leaving no evidence of any breach of continuity. Some of these streams surround the spines, and run up and down them like the mobile cortical layer on the axis-fila-

ment of the pseudopodia. Grenacher has described a central rather large stellate space containing a clear liquid, and having in its centre a little spherical corpuscle, from which radiate a multitude of very fine lines which he believes to represent the continuation of the axis-filaments of the pseudopodia. This observation has been accepted in its essential points by Greeff, though neither Archer nor Hertwig and Lesser have as yet succeeded in satisfying themselves of its correctness.

Reproduction takes place by a direct division of the entire animal into two parts. Greeff has also observed a peculiar encysting process in which the sarcode body withdraws itself from the outer walls, contracts into an internal globe, and becomes surrounded by a hyaline organic membrane. The spines still remain on the outer walls; but the pseudopodia have disappeared, and the surface becomes covered by a delicate hyaline, but strong and impenetrable, siliceous investment. The pale glistening homogeneous spherules which accompany the green granules now undergo a rapid increase, and are probably the spores of the *Acanthocystis*; but Greeff has not succeeded in following the process further, and its true import remains undetermined.

Notwithstanding the fact that *Acanthocystis* is destitute of the essential points of Radiolarian structure enumerated above, Greeff maintains its close affinity to the Radiolaria. The outer siliceous skeleton, with pseudopodia emitted between the spines, and having their firm axis coming from the interior of the protoplasm, and apparently from a central capsule-like structure, are all points on which he insists as affording evidence of close Radiolarian relations; and he accordingly assigns to *Acanthocystis* a position in the neighbourhood of the Acanthometridæ of Haeckel.

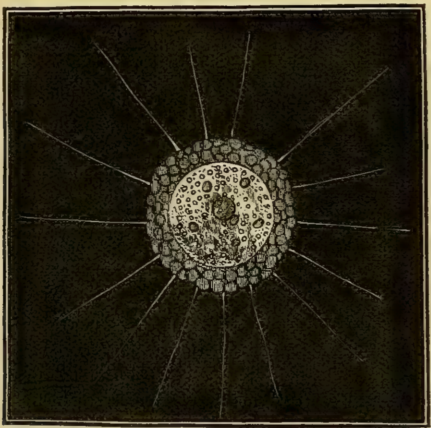
Some other species of *Acanthocystis* have also been described. Of these, *A. spinifera*, Greeff, has been well studied by Hertwig and Lesser, who have pointed out a very decided differentiation between ectosarc and endosarc. They describe contractile vesicles in the ectosarc, and in the endosarc an eccentric nucleus with nucleolus.

Among other forms which are characterized by the presence of certain hard or skeletal structures must probably be placed the genus *Astrodisculus* of Greeff.

Greeff gives the generic name of *Astrodisculus* to certain freshwater Rhizopoda, among which he has distinguished several species, which are all rendered striking by the central sarcode body being surrounded by a broad clear zone. This outer

zone is composed of a soft hyaline substance, and, according to Greeff, is bounded externally by a very delicate siliceous capsule, perforated by minute openings, through which the pseudopodia are emitted, and through which Greef believes he has seen nutritive corpuscles pass. The existence of a perforated siliceous capsule, however, has not been accepted by other observers; and Hertwig and Lesser think it probable that all the species referred by Greeff to his genus *Astrodisculus* would with more justice go into Greeff's genus *Hyalolampe*, identical with the *Pompholyxophrys* of Archer.

Fig. 14.



Hyalolampe fenestrata—the protoplasm body, with its nearly central nucleus, surrounded by its siliceous test, between whose component spherules the pseudopodia are emitted. (After Greeff.)

Greeff describes*, under the name of *Hyalolampe fenestrata* (fig. 14), a most interesting and characteristic form, in which the sarcode body is surrounded by a very elegant siliceous shell, which has the appearance of being formed of little glass spheres laid one on the other. He believes the shell to be perforated for the emission of the pseudopodia.

Nearly simultaneously with Greeff, but claiming the priority by some days, Archer had described, under the name of *Pompholyxophrys punicea*, the same rhizopod, which he found not unfrequently in moor-pools in various parts of Ireland. It has been more recently examined by Hertwig and Lesser†, who have supplemented and corrected the descriptions given by Greeff and Archer.

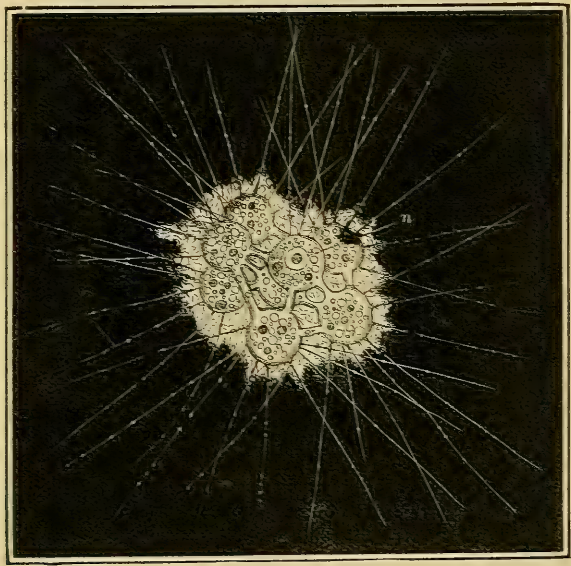
* *Loc. cit.*

† *Loc. cit.*

They have verified Greeff's description of the skeleton as composed of layers of hyaline siliceous globules; but, like Archer, they fail to discover perforations in it, and find that the globules are but loosely connected with one another and are easily detached during the passage between them of nutritive matter. There is a single nucleus, and also contractile vacuoles. The pseudopodia which pass out between the siliceous globules are destitute of granules, and rarely show any tendency to branch.

Another beautiful genus of skeletophorous Heliozoa is *Raphidiophrys*, Archer. In the species referable to this genus the spherical body-mass is probably in every case differentiated into en-

Fig. 15.



Raphidiophrys elegans. A colony of eight individuals united to one another by bridges of protoplasm, the whole surrounded by a soft granular investment, in which are immersed minute curved spicula, and through which the pseudopodia are seen passing from the inner spheres to the surrounding water. *n*, nucleus, with its nucleolus visible in one of the component spheres. (After Hertwig and Lesser.)

dosarc and ectosarc, and contains in the endosarc a single nucleus, while from the periphery radiate in all directions very long unbranched granular pseudopodia.

External to the proper protoplasm-sphere is a soft granular

investment, in which is immersed an immense number of tangentially or irregularly disposed, curved siliceous spicula, and through which the pseudopodia pass from the surface of the inner sphere to the surrounding water. The species of *Raphidiophrys*, however, are usually found in the condition of colonies. One of these colony-forming species, *R. elegans* (fig. 15), has been described and figured by Hertwig and Lesser as a cluster of globes united rather loosely to one another by thin bridges of protoplasm, across which the sarcode currents may be seen passing from one globe to the other, while the whole cluster is surrounded by the common soft investment in which the spicula are immersed, and which allows the passage across it of the long fine pseudopodia from the periphery of the included globes.

R. viridis, one of the finest of all the freshwater Rhizopoda, is described by Archer*, who has taken it as the type of the genus. It is also a colony-forming species, and is distinguished by its bright green colour, caused by a dense stratum of chlorophyll granules which lie just within the periphery of each of its component spheres.

Under the name of *Pinacocystis rubicunda* (fig. 16), Hertwig and Lesser have described an interesting skeleton-bearing heliozoan which they found in sea-water. Its spherical body is surrounded by a case which consists of isolated round tablets lying close to one another, and thus forming a completely closed capsule. They compare this capsular skeleton to that of an *Acanthocystis*, in which the whole of the spines, with the exception of their basal plates, had disappeared.

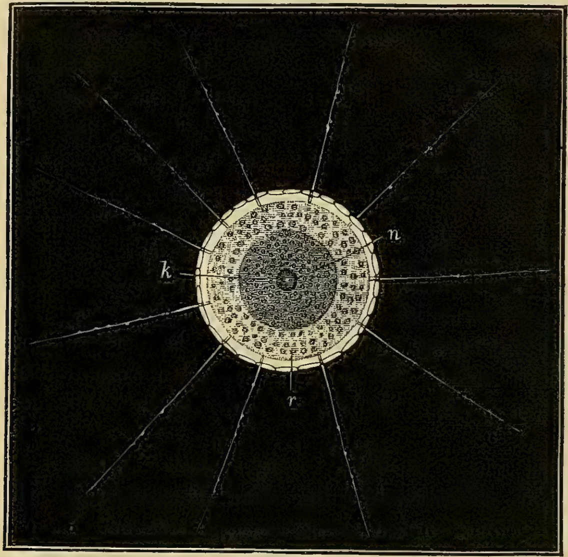
The protoplasm body is separated from the capsule-walls by an interval which would seem to correspond to the similar interval between the body and the basal plates of the spines in *Acanthocystis*. The protoplasm shows a very decided differentiation of ectosarc and endosarc. The ectosarc is loaded with brownish-red granules; and the endosarc contains a single nucleus. Contractile vacuoles could not be demonstrated. The pseudopodia are emitted through the intervals of the capsule-tablets.

A closely allied form is that of *Pinaciophora fluviatilis*, Greeff. This heliozoan was found by Greeff in freshwater streams. It resembles *Pinacocystis*, Hert. & Les., in being surrounded by a globular capsule composed of separate though closely approximated plates, but differs from it in the oval form of these plates.

* Quart. Journ. Micr. Sci. vol. xi. 1871.

and in the fact, according to Greeff, that they are traversed by minute canals for the transmission of the pseudopodia. There is a large central nucleus with nucleolus.

Fig. 16.



Pinacocystis rubicunda. *k*, endosarc; *r*, ectosarc; *n*, nucleus. (After Hertwig and Lesser.)

Acanthocystis and the other skeletophorous Heliozoa whose hard parts are in the condition of detached pieces such as spines, spicula, tablets, and the like, have been united by Hertwig and Lesser into a group to which they give the name of CHALAROTHORACA, while those whose skeleton is in the form of a connected shell have been combined into a separate group under the name DESMOTHORACA.

Among the Desmothoraca the most interesting is *Clathrulina elegans* (fig. 17), originally described by Cienkowski, who discovered it near St. Petersburg*. Greeff now gives a very full description of this beautiful little Rhizopod, which he obtained in the neighbourhood of Bonn. It had also been found by Haeckel near Jena, while a closely allied, if not identical form had nearly simultaneously with Cienkowski's discovery been observed by Archer in Ireland and in Wales.

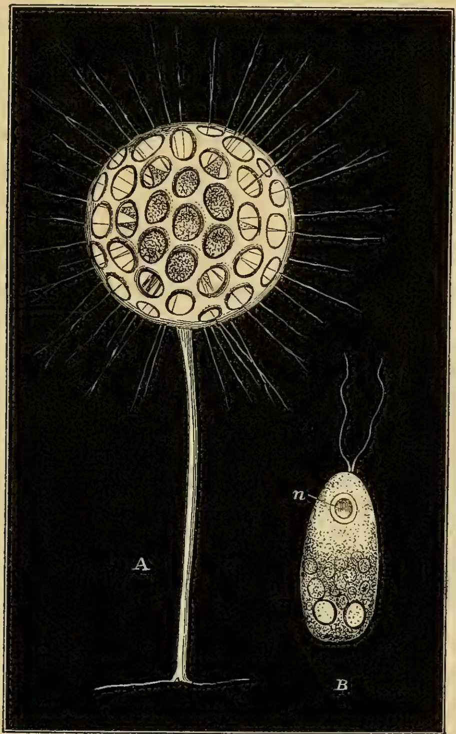
* Cienkowski, "Die Clathrulina," Archiv f. micr. Anat. 1867.

It occurs chiefly in dark ponds shaded by trees and containing decaying leaves. Its soft sarcode body is included in a siliceous capsule of a spherical form regularly perforated in the manner of latticework, and supported on a long siliceous peduncle.

Pseudopodia are projected through the latticework of the capsule; and these, as in the Actinophryidæ, are composed of an axis-substance, and a cortical substance. The axis has been followed into the interior of the protoplasm. Vacuoles which hold no stable position are scattered through the protoplasm; and there is a vesicle-like nucleus, which is rendered evident by the application of acetic acid.

Cienkowski had already shown the occurrence in *Clathrulina*

Fig. 17.



Clathrulina elegans. A. The completely developed rhizopod (after Greeff). B. A swarm-spore of *Clathrulina elegans* (after Hertwig and Lesser): *n*, nucleus; *c*, contractile vacuoles.

of two kinds of reproduction, by division and by cyst-formation. The former takes place within the capsule, and consists in the division of the contents by a transverse constriction. One of the two portions thus formed soon forces its way out through the perforated capsule, and then lives for some hours in the surrounding water as a free naked sarcodic body resembling an *Actinophrys*. It ultimately secretes a capsule and stem, and becomes a perfect *Clathrulina*.

In the second kind of reproduction there are formed within the capsule, by a process apparently of budding, numerous rounded sarcode-masses, each of which becomes enveloped by a firm covering; and they thus remain for months as spherical cysts within the common capsule. Greeff has further examined these bodies, and has shown that they contain within them a large pale nucleus, and that the walls of the cyst are set round with short spines, and are probably siliceous.

When the time has arrived for their further development, the sarcode contents slip out of their cysts and escape into the surrounding water through the latticework of the capsule. Here they swarm about for some hours in the form of ciliated oviform embryos, then become transformed into free *Actinophrys*-like organisms, which finally acquire the stem and siliceous lattice-like capsule of the perfect animal.

The resemblance of the siliceous perforated capsule of *Clathrulina* to the latticed shells of the Polycystina is sufficiently obvious; and we must admit, with Greeff, that, if we met with these little capsules free in the open sea, we should not hesitate to refer them to the true Polycystina, and place them in Haeckel's Radiolarian family of the Ethmosphæridæ. In the more essential points of structure, however, *Clathrulina* has no close affinity with the Radiolaria, from which it is widely separated by the absence of a central capsule with its multicellular contents. The absence of yellow cells is another, though less important, point which opposes itself to the association of *Clathrulina* with the true Radiolaria. Notwithstanding these differences, however, Greeff does not hesitate to refer it to the Radiolaria, and place it there, in the family of the Ethmosphæridæ.

Another Desmothoracous genus has been described by Hertwig and Lesser under the name of *Hedriocystis*. Like *Clathrulina*, the body is enclosed in a single-chambered stalked test perforated for the passage of pseudopodia; but instead of being hard and

Fig. 18.

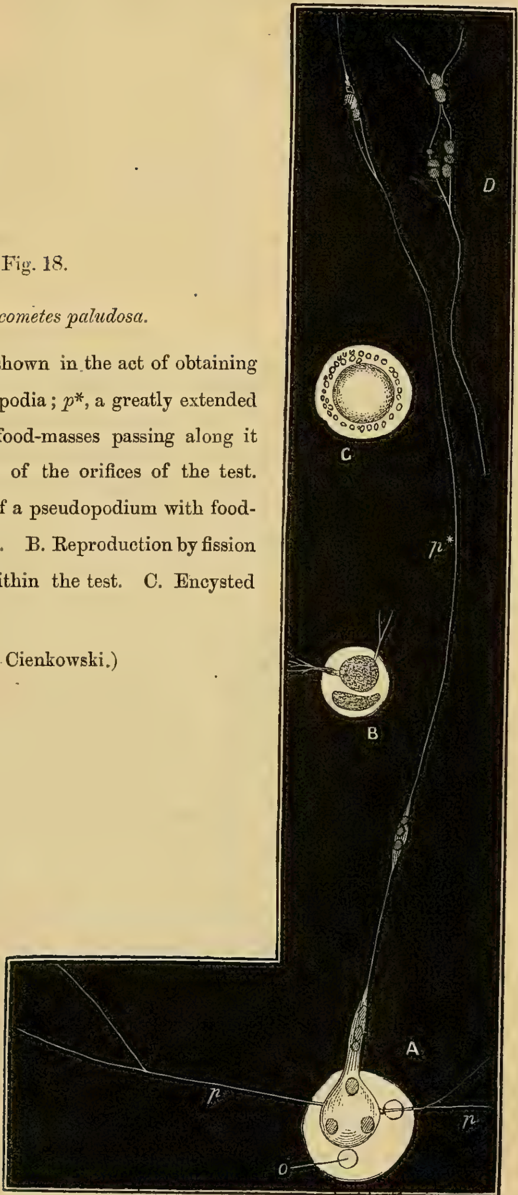


Fig. 18.

Microcometes paludosa.

A. An individual, shown in the act of obtaining its food; *p*, *p*, pseudopodia; *p**, a greatly extended pseudopodium with food-masses passing along it to the body; *o*, one of the orifices of the test. D. Distal extremity of a pseudopodium with food-particles engaged in it. B. Reproduction by fission of the protoplasm within the test. C. Encysted condition.

(After Cienkowski.)

rigid as in *Clathrulina*, it is soft, thin, and flexible, and at the perforation is continued as a very short tubular prolongation round the pseudopodia. The round protoplasm-body does not fill the cavity of the shell, but swings in it free as if hung on the pseudopodia which perforate the shell-walls. It contains an oval nucleus with nucleolus; and close to its margin are situated one or more actively pulsating vacuoles.

Reproduction by division of the body into two segments was observed with great distinctness.

Only a single species, *H. pellucida*, has as yet been discovered. It is found attached by its stalk to the filaments of Algæ and other foreign bodies.

To the Heliozoa rather than to any other group must probably be referred another interesting form which has been assigned by Cienkowski to a new genus*. He gives it the name of *Microcometes paludosa* (fig. 18). He found it in Russia among gelatinous algæ. The protoplasm-body lies free in the interior of a loose membranous capsule, whose wall, perforated in a few places, affords passage to the very long pseudopodia. The histological differentiation of its body is that of most Heliozoa, having a nucleus with a nucleolus, while two or three contractile vesicles exist in the peripheral layer. The pseudopodia, which are thrust out through the perforations in the shell, are but little branched, and are sometimes extended to a great length, in order to reach the food at a distance. The end of the pseudopodium may then be seen to flow round the nutritive particle such as an alga-spore, which, when thus captured, will move along the path of the protoplasm filament until it reaches the interior through one of the openings in the shell. During this transport the pseudopodial filament lies immovable, while new nutriment-particles move along it into the capsule.

Besides the reception of food being thus effected by the pseudopodium enveloping the nutritious particle, the *Microcometes* has also the power of perforating alga-cells with the extremity of a pseudopodium, and then sucking out their contents in the manner of a *Vampyrella*.

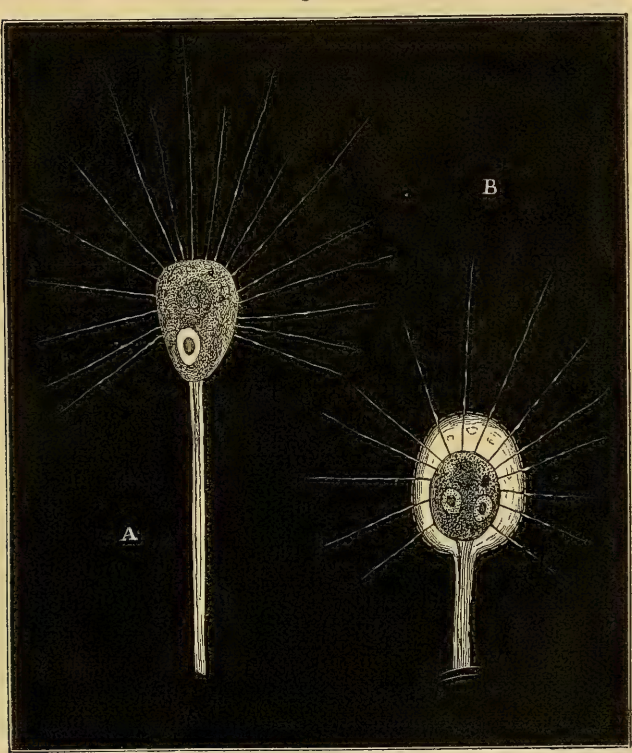
Multiplication takes place by the division of the protoplasm-body into two parts, which are pressed out through the narrow apertures in the capsule. In the development-cycle there has also been observed a resting-state, in which, without leaving its capsule,

* Arch. f. micr. Anat. vol. xiii.

the body assumes a spherical shape, and, after expelling the undigested remains of the nutriment, envelops itself in a thick membraue.

As an aberrant form of the Heliozoa, from the typical members of which it departs chiefly in the want of the permanent spherical (homaxial) form, may here be included the *Actinolophus pedunculatus* (fig. 19) of Fr. Eilhard Schulze. Under this name Schulze described a remarkable pedunculated Rhizopod which attaches itself to marine Algæ and to *Gonothyræa Loveni* and other Hydroids. It presents itself in two different states. In one the body is quite destitute of hard parts; in the other it is invested by a siliceous covering.

Fig. 19.



Actinolophus pedunculatus. A. State in which the body is destitute of hard parts. B. State in which the body is invested by a siliceous scaly covering through which the pseudopodia pass outwards to the surrounding water.
(After Schulze.)

In the first state the body has usually the form of a pear, attached by its narrow end to a long cylindrical stem. It is very contractile, however, and may assume a spherical or an egg-shaped form. No external membrane or definite cortical layer can be detected. In its interior there is always a very excentric nucleus enclosing a very large nucleolus. In the centre of the wide part of the animal lies a dark spherical body, whose true nature has not been ascertained. Its position generally corresponds to the point in which the pseudopodia if prolonged inwardly would meet; and Schulze thinks that in some cases he could trace fine lines from it to the pseudopodia. In some specimens there occurred, besides the ordinary granules, numerous orange-red corpuscles, which, along with large nutriment-pellets, lay near the periphery. No pulsatory vacuole was found*.

The pseudopodia occur only on the more distal part of the body, from which they radiate in all directions. The appearances are in favour of the pseudopodia being composed of a central firm axis and an investing cortical layer; but on this point the author cannot speak decidedly. A complete withdrawal of the pseudopodia was never seen, the contraction of these processes being at a definite distance from the surface of the body suddenly stopped, as if by the presence of a thick perfectly hyaline investment, which the author thinks is really present in the form of a gelatinous excretion from the body, but which, from its extreme transparency, is all but invisible. In this state the pseudopodia present the appearance of fine lines tipped each with a little granular mass of sarcode, and the *Actinolophus* closely resembles a *Podophrya*.

The stem is cylindrical, hyaline, and appears to be encased in a delicate sheath. In its interior may be seen several parallel, straight, longitudinal lines.

Besides the individuals so formed, others occur with a manifest outer envelope. This shows itself at first as a gelatinous investment, so transparent as to be recognized only by its boundary contour. It is traversed by the pseudopodia and by the fine parallel lines from the interior of the stem. In a stage further advanced, a layer of very delicate strongly refringent plates has formed on the surface of the gelatinous mantle, and is continued downwards over the stem. The plates appear to be composed of silica, and ultimately acquire a tolerably regular hexagonal form, but never come so close as to touch one another by their edges.

* F. E. Schulze, "Rhizopodenstudien," Arch. f. micr. Anat. vol. x. 1874.

Simultaneously with the formation of the siliceous investment certain changes are going on in the interior. The nucleus divides into two; and each half, surrounded by a peculiar clear area, recedes more and more from the other. The pseudopodia remain at first quite unchanged and fully extended; but by the time that the siliceous case is completed they have become entirely withdrawn, while the dark central body has at the same time disappeared.

The condition thus attained is probably a true encysted or resting-state, to be succeeded by a division of the contents; but Schulze was unable to follow it to its ultimate destination.

The various organisms which I have now passed before you in review are confined to certain more purely Amœboid forms and to the recently established group of the Heliozoa. We are indebted, however, to recent investigations for our knowledge of many other sarcodic beings, which, whether regarded in their completed forms or in their developmental history, are of great interest. Their introduction here, however, would extend the present address to a length far beyond its legitimate limits; and their consideration must therefore be deferred to a future occasion.

Contributions to the Ornithology of New Guinea. By R. Bowdler Sharpe, F.L.S., F.Z.S., &c. Part II.—On the Ornithological collections formed by the late Dr. James in South-eastern New Guinea and Yule Island.

[Read March 15, 1877.]

The localities where the collection now about to be described was formed, are well known to naturalists as the hunting-grounds of the Italian traveller D'Albertis, who has made us acquainted with the features of the ornithology of Yule Island and the opposite coast of New Guinea. A melancholy interest attaches to the present collection of Dr. James; for it is at once the first, and last, that we shall receive from him. This young naturalist, whose career as a traveller commenced so favourably, and whose energy trampled on so many difficulties, was murdered by natives, as mentioned in a communication of the Rev. S. Macfarlane in 'Nature' for Nov. 16, 1876:—"We have just heard of the massacre of Dr. James and his partner, a Swede, at Yule Island